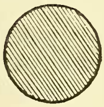
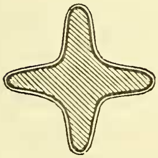
first see existing faults rectified, and then at intervals of, say, not more than three years, examine and test every conductor.

In conclusion, I would quote the following words from the report of the conference: "There is no authentic case on record where a properly constructed conductor failed to do its duty."

The subjoined diagrams illustrate the conductors at the Melbourne University. These are very much superior to many in use elsewhere; nevertheless they would all be condemned under the Code of Rules, and the newer type is distinctly inferior to those used on the oldest part of the building.



Old Conductors—Half-inch iron rod; area, ·196 square inch; joints every twenty feet; screw couplings.



New Conductors—Iron, covered with very thin copper; three contact joints every twelve feet; area, about ·15 square inch, of which about one-sixth is copper.

Art. XI.—*On the Official Reports of the Tarawera Outbreak, with Objections to some of the Conclusions drawn by the Government Geologist, Dr. Hector.*

By G. S. Griffiths, Esq.

[Read 9th September, 1886.]

In reading the official report of this outbreak, it will be noticed that Dr. Hector describes his chief object in visiting the scene of activity as being "to ascertain the exact locality, nature, and extent of the outbreak, and its probable consequences to the district."

The views that he formed after he had examined the district are summed up by him as follows:—He concludes that the eruption was (1) a purely hydrothermal phenomenon; (2) that it was not of deep-seated origin; (3) that it was a quite local movement; and he also tells us that the great fissure was the most characteristic feature of the outbreak.

What I propose to do is to discuss Dr. Hector's views as to the nature of the eruption as far as the facts disclosed in these two reports will enable us to do so.

We will, in the first place, consider the statement that it was a purely hydrothermal phenomenon.

Now, what is a purely hydrothermal phenomenon?

Must a phenomenon, to be termed purely hydrothermal, have heated water, and nothing else, as its cause, and also heated water, and nothing else, as its effect? If so, then hot springs and geysers alone are purely hydrothermal phenomena, and Dr. Hector's meaning must be that Tarawera was merely a geyser.

But it is certain that Dr. Hector might mean to describe a phenomenon of which the sole cause was heated water, although the visible effects included the emission of many kinds of matter besides steam and water. Such a phenomenon would be a volcano, and if I accepted Dr. Hector's words in this sense, then his meaning would be that the sole cause of the Tarawera outbreak was the action of heated water. But such a statement would be the merest truism, and therefore it is unlikely that he would make the assertion.

Consequently, it will be necessary to weigh the language of the context to enable us to decide whether he means to say that Tarawera was a mere geyser, or that the Tarawera volcano was actuated purely by steam.

Thus he tells us that it was a hydrothermal phenomenon, but upon "a gigantic scale." Now, if it were a geyser eruption, it certainly was one upon a gigantic scale; but if it were a volcano, its scale was not at all gigantic, but very ordinary. Therefore, from the use of this adjective we would infer that he is describing a geyser.

Again, he states that the outbreak was "not deep-seated." This raises the question as to whether volcanoes are ever superficial in their origin. I shall discuss this point further on, and at this stage I will only say that such a statement confirms the impression already made on my mind that a geyser, and not a volcano, is conceived of by the author of the report.

The use of these qualifying words in relation to the scale and to the origin of the eruption decides me that Dr. Hector, when he used the phrase "a purely hydrothermal phenomenon," meant to assert that Tarawera is a geyser, and not a volcano.

Now, what is the difference between a volcano and a geyser? They are alike as to their causes. Both of these forms of activity are due to the same agent. Each is a natural steam-engine. Each requires to have water in its chambers before it can operate, and without water can no more act than can a locomotive with a dry boiler. But if they agree in their motive-power, they differ greatly in the mode in which they eject solid matters; and they differ even more widely in the nature of the material ejected.

Geysers emit usually only water and steam, but occasionally they eject stones. Such stones are, however, always of superficial origin; they are rocks which have been torn out of the vent by the steam blast; they are derived from its throat, and not from its stomach. The ejectamenta of a volcano are, on the contrary, drawn mainly from its stomach—that is, they are principally of plutonic origin. Only a small proportion of the output is derived from the throat, and this part is ejected chiefly at the beginning of the outbreak, while the fissure is forming, or when the plug is being blown out. Therefore, the first difference between a geyser and a volcano is that the former ejects only steam and the materials of the neck, whereas volcanoes vomit the contents of their deep-seated reservoirs as well as the contents of their vents.

The second difference between them is a direct consequence of the first.

While the solid ejecta of geysers is unfused country rock, and never consists of lava, scoria, or ash, volcanoes eject all these materials, and the country rock from the neck is, as often as not, more or less fused.

Consequently, we should be able to decide as to whether Tarawera is a volcano or whether it is a mere geyser, as Dr. Hector contends, by an examination of its ejectamenta.

Both Dr. Hector and Mr. Percy Smith describe the materials erupted by Tarawera, and they tell us that 1800 square miles of country have been buried more or less deeply under sand, ash, and tuff, mingled with fragments of old trachytic lava, the latter being the country rock drilled out of the vent.

Dr. Hector also presents to us an analysis of the dust from Tarawera, and it is constituted as follows:—

Obsidian Ash from Tarawera. (Dr. Hector's report.)		Obsidian.	Andesitic Lava.	Diorite or Syenite.	
Si. ...	59·37	60 to 80	59·75	54 to 59	59·83
Iron oxides ...	10·18	3 to 7	7·57	10 to 14	7·01
Al. ...	17·96	18 to 19	17·25	16 to 18	16·85
Manganese ...	traces	—	—	—	—
Ca. ...	5·98	1·1	6	6 to 7·5	4.43
Mag. ...	1·19	0·6	1·30	6	2·61
Phos. acid ...	traces	—	—	—	—
Water ...	2·21	—	1·0	—	1·29
Soluble salts ...	traces	—	—	—	—
Organic matter	·99	—	—	—	—
Alkalies ...	2·12	9·2	7·10	—	9·18

Now, we are sufficiently well-acquainted with the nature of volcanoes to be able to say that an obsidian ash of the composition given above has been derived from that variety of lava which has been named andesite, and that andesitic lava in its turn has been derived from a reservoir of molten diorite. I therefore give the elements of these rocks side by side with those of the ash, so that you may see at a glance their elementary kinship.* These three forms of the same substance (obsidian, andesite, and diorite) result entirely from their elements cooling under different conditions; but their fundamental agreement is disclosed in their identical composition. This volcanic dust consists of a mass of broken glass bubbles and spiculæ, which could not have been derived from the throat of a geyser, for it has required for its elaboration conditions available only at great depths. If Tarawera has ejected an ash which must have been elaborated at great depths, then we must admit that it must have a deep-seated origin; but we have already noted that Dr. Hector denies this. He declares that its origin is not deep-seated, but he neither tells us what he

* The relationship of the various plutonic rocks to the volcanic forms is stated thus by Professor Judd :—

	Granitic Forms.	Lava Forms.	Glassy Form.
Acid ...	Granite ...	Rhyolite ...	Obsidian
Intermediate	Syenite ...	Trachyte ...	Do.
Intermediate	*Diorite* ...	*Andesite* ...	*Do.*
Intermediate	Miascite ...	Phonolite ...	Do.
Basic ...	Gabbro ...	Basalt ...	Tachylyte

believes to be its absolute depth or what he would call deep or shallow. This phrase of his, then, as descriptive of position, is of vague and uncertain meaning, for depth is relative and ideas differ. The depth that would be great for a shaft would be shallow for a volcano, and, compared with the globe-bulk, the greatest sea-depth is superficial. Now, it is impossible for any one to prove, in absolute measure, what the position of the focus is; but I think I have shown that its depth must be that of a reservoir capable of holding for a long period molten diorite mixed with water at a white heat. Therefore, it seems to me that Dr. Hector can establish his contention of a shallow origin for Tarawera only by showing us that diorite can be elaborated under a crust which, judging by an analogy, is too thin to afford it either great pressure or a hermetic cover, and within a furnace the wall of which is not thick enough to retain the heat required to fuse its materials.†

Taking into consideration the plutonic nature of the ejected materials, therefore, I am unable to accept Dr. Hector's conclusion that Tarawera is a geyser eruption.

But when we have decided in our own minds that it is a volcano and not a geyser, there is still room left for further inquiry into its nature, as volcanoes are of several types, distinguished from each other by important differences. For instance, Dr. Hector does not notice in his report what appears to me to constitute the essence of the nature of this eruption—namely, that it is a fissure eruption and not a crater eruption. Certainly, he points to the fissure, and terms it "the most remarkable and characteristic feature of the late eruption;" but while he recognises the greatness of the feature as a part of the landscape, he does not say a word to indicate that he recognises the real importance of the fissure to rest upon the fact that it supplies the key which explains a great enigma in the mechanics of Tarawera, which otherwise would puzzle us.

This enigma may be stated as follows:—The Tarawera vent was charged with lava; the vent was so low in position that it was level with the lake; the lava was charged with an abundance of interstitial steam, and yet no lava was erupted. Why, then, with all these favourable conditions present, was there no emission?

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† Judd estimates that the Granites have consolidated under the pressure of depths varying between 30,000 feet and 80,000 feet. *Volcanoes*, p. 253.

We can understand why Cotopaxi erupts rarely, because we know that the lip of its crater is placed more than 19,000 feet above the level of its reservoir, and we allow for the enormous resistance which must be overcome before the column of lava can be forced up to the top of so lofty a chimney. But at Tarawera there was no chimney—the vent was an open chasm in the valley floor.

Again, we can understand a volcano in the Solfatara stage not erupting, for when in that stage the water has run short, or the fires have got low. But here steam was present in such abundance as to lead Dr. Hector to describe the affair as "a purely hydrothermal phenomenon."

And, again, we could understand it if, with an abundance of steam and with an easy exit, there was no lava present. But we know that there was an ample supply here, because every uprush of steam loaded the air with obsidian, which is the froth of bubbling lava. Why, then, I repeat, was no lava erupted at Tarawera?

To make the explanation clear, let us remember our former simile. I said that a volcano was a natural steam-engine. Now, a steam-engine will not work well, will not generate a high horse-power, however well supplied with water and fire, if its boiler have a leak; and if the leak be a large one, it will wholly disable the engine, so that its steam, instead of being utilised, will escape idly in great white clouds, and with a prodigious roar. Such, then, exactly represents the course of events at Tarawera. The subterranean steam burst through the crust that confined it. The crust had no weak spot in it, such as the small circular plug which is blown out of the vent when Vesuvius, Etna, Hecla, or Tongariro erupt. It had, therefore, to break through a sound crust, and it did so with a long rent.

Where there is an ordinary crater-vent, such as these volcanoes named have, its size just suffices to give gradual relief to the high-tension vapour imprisoned below, but it is not large enough to permit of a free escape. Consequently, the interstitial steam has a struggle to reach the vent. It expands as it reaches the region of lessening pressure, and the expanding bubbles, as they hurry through the passages, crowd before them a great volume of liquid aërated lava, which thus boils over the lip in exactly the same way that water or milk will do. But the Tarawera vent was not a circular crater of limited size, but a fissure eight or nine miles long, and, in places, one mile wide. Such a vast chasm has an effect which corresponds to that of the leak in the locomotive boiler, or to that of the rupture of an aneurism in some great artery. It provides the lava with such an extent of free surface that its steam escaped without effective effort—that is, without accumulating anywhere hydrostatic pressure enough to lift the lava over the lip. Thus the pumping-up power is lost, and only lava bubbles escape, and these, saturated with high-tension steam, explode into dust at the moment of complete relief.

It will be seen, therefore, that the size of the rupture fully accounts for the absence of a lava flow, and is the key to the character of the outbreak.

Tarawera will become notable because it is an example of the comparatively rare fissure-type of eruption, instead of being one of the familiar cone-and-crater type.

It is now believed that every volcano has commenced as a fissure. The fissure is sealed up when the first great steam escape has ceased, excepting at one or two points where small cones form and let off the residue, and then become plugged up in their turn. In time steam accumulates again, and ultimately a second phase of eruptivity commences. In this revival of activity the fissure does not reopen, but only the cones, which this time erupt lava and ash, and grow rapidly in size, so that in time the old fissure is buried under either a chain of small craters or under one large volcano. Whether or no such a development as this is to be the sequel of Tarawera only the future can tell us.

The meteorological conditions which accompanied the eruption are hardly referred to in the official reports.

From other sources we gather the interesting fact that it occurred at a time when an area of barometrical depression passed over that end of New Zealand. Mr. Cheeseman, the Government Meteorologist, states that at 4 a.m. on June 9th the barometer stood at 30·27, but that it then fell until it touched 29·94, or a drop of one-third of an inch, at which it stood until 4 a.m. of the 10th, the morning of the outbreak, when it began to rise again.

Unfortunately, we have no barometrical readings from the immediate neighbourhood of the disturbance, but the New Zealand papers give a singular story, which points to a heavy fall at Wairoa. It is stated that during the bitterly cold morning when the eruption was at its climax, some of M'Rae's party lit a fire to make a drink of cocoa, but that at the end of three-quarters of an hour, and although the water in the billy bubbled, it never became heated nearly up to the ordinary boiling point, and the men, struck with the strangeness of the phenomenon, concluded that it was an "uncanny" omen, and so abruptly abandoned their task.

If this story has a substratum of truth—as it well may have—it would indicate an excessive barometrical fall over Wairoa during the eruption. Such a fall might have been due to the enormous volume of superheated steam and gas which was projected into the atmosphere, and which, accumulating round and banking up over the vent, as a dome-shaped cloud, would give to the several planes of pressure enveloping it, a sharp, short, quâ-quâ-versal dip, down which the cold and dense, and therefore heavier strata of superincumbent air, would quickly slide away to every point of the compass, piling up at the bottom of the slope, as an atmospheric talus, and so forming a peripheral ring of higher pressure round the volcano, but at a little distance from it. The displacement of such a volume of heavy air by an equal volume of attenuated air would register itself at the earth's surface below it in a fall of mercury, and it would lower the boiling point of water for every altitude within the same area. Thus it would render the newspaper story quite possible.

Again, it is well to remember that the abrupt creation of such a disposition of the atmosphere would account for the tornado blast which played such havoc near the volcanoes during the second phase of the eruption. For, over the fissure, the ascending vapours must have operated as an atmospheric chimney, and this would create a powerful indraught of low-level air, and the enclosing ring of high-pressure—that is, the atmospheric talus before suggested—would, if it existed, increase the indraught.

It would be very interesting to learn all the wind movements which occurred that morning round the volcanoes.

The official reports give the changes at Wairoa and Rotorua only; but these two places are situated in the same quadrant of a cyclone centred over Tarawera, and the absence of settlement in the surrounding region will render it almost impossible to get the information desired.

Still, we ought to get some information as to the direction taken by the great tornado from the bearings of the fallen trees, and some more general information from the distribution of the ejecta.

These official reports mention the levelling of the forests by the storm, but they do not say whether any attempt to use the tree-trunks as anemographs has been or will be made.

The distribution of the volcanic deposits is well shown on Dr. Hector's map. The mud lies in a straight, broad track, the axis of which bears about one point west of north. This should indicate the prevalence of a steady wind from the south or near by.

Yet the people at Rotorua state that the wind there was first from the south-east, and that it then blew with great violence from the south-west. If the south-westerly direction of the wind had prevailed generally, it would have carried the falling mud away to the north-east of the volcano, which it certainly did not do according to Dr. Hector's plan.

It appears to me that the mud distribution is more consistent with the theory of a local indraught, and that the wind direction at Rotorua was a purely local phenomenon.

The sand, again, is distributed over a differently-shaped and a differently-placed area. Instead of having a long band we have an oval. It has fallen far to the eastward of the mud track, and also some miles to the south of the vents. From the latter circumstance it is clear that over this part of the area, during some part of the time, or at some altitude, a wind must have blown from the quarter exactly opposite to that of the wind which spread the mud.

The grey ash is distributed over an oval also, but the oval is a much larger one.

The discrepancies between the tracks of the several dust-clouds and between these and the recorded winds may be susceptible of the following explanation:—It may be that at the earth's surface a broad zone of southerly wind prevailed, within which a small cyclone raged round the volcanoes, like an eddy in a wide river. The main stream may have carried along the heavy mud, and so have preserved to it the straightness of direction which is so marked a feature of its distribution. The dust, which was carried at once into the higher regions, escaped the wetting which made mud of that which remained within the plane of the southerly wind, and being light, because dry, it was easily whirled about to different points by the different winds, or by the gyratory movement which was prevailing above.

The *Argus* reporter has described how a spectator at Rotorua saw a black dust-cloud driving, apparently, dead to windward, and in the teeth of a south-west gale which was then raging at that place. This appearance is what would be expected if the lower winds over a limited area were approaching an inverted vortex, and the upper winds, laden with ash, were sliding outwards and downwards, and distributing their loading all around, after the manner of a gigantic Jupiter.

The last point to which I desire to allude briefly is the relation of the time of the occurrence of this eruption to those periods of maximum frequency of earth disturbances which some physicists have deduced.

It has been noted that in this hemisphere the several periods of earthquake maxima occur in the winter season, in the month of June, during the night time, and between midnight and half-past two a.m.

It is not necessary for me to do more than point out that the Tarawera eruption occurred at ten minutes past two in the night time, during the month of June, and in the winter season.

G. S. GRIFFITHS.